AMERICAN MUSEUM NOVITATES

Number 995 Published by THE AMERICAN MUSEUM OF NATURAL HISTORY New York City June 3, 1938

A STUDY OF PROPORTIONAL CHANGES DURING THE POST-LARVAL GROWTH OF THE BLUE MARLIN (*MAKAIRA NIGRICANS AMPLA* POEY)[1]

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ACKNOWLEDGMENT

The material which serves as the basis for this study was secured by the Michael Lerner Bimini Expedition of The American Museum of Natural History during July, 1937. This data consists of absolute measurements of numerous parts and organs of twenty-three specimens of the blue marlin, *Makaira nigricans ampla*, as given by Conrad and LaMonte (1937) in their paper on the description of the body form of this species. Many thanks are extended to Dr. William K. Gregory, under whose supervision this study was carried out, for his criticism and clarification of the problems raised in this paper, and to Dr. Edmund Sinnott for his useful suggestions concerning the methods and procedure. Acknowledgment is also made to Mr. G. Miles Conrad for his suggestions and criticisms and for his information concerning many details of the orginal material.

INTRODUCTION

The constant differential growth ratio of Huxley affords a means of studying the relation that various parts of an organsim have to each other or to the organism as a whole as that organism or its parts are increasing in size. The rates of growth of various parts are thus an indication of the proportional changes occurring during the period of growth of the individual. Proportions may change by the organ in question

[1] Results of the Michael Lerner Ichthyological Expeditions. No. 13. Also the first in a series of papers to be titled, 'Studies on Heterogony (Allometry) in the Vertebrates.'

Previous publications in the Results of the Michael Lerner Ichthyological Expeditions series:

No. 1.—(Photographs). Natural History, January, 1937, pp. 58–59.
No. 2.—Conrad, G. M.: American Museum Novitates, 1937, No. 900.
No. 3.—Nichols, J. T., and LaMonte, F.: American Museum Novitates, 1937, No. 901.
No. 4.—Raven, H. C., and LaMonte, F.: American Museum Novitates, 1937, No. 902.
No. 5.—Weisman, A. I., Mishkind, D. I., Kleiner, I. S., and Coates, C. W.: Endocrinology, 1937, XXI, No. 3.
No. 6.—Nichols, J. T., and Raven, H. C.: Journal Mammalogy, 1937, XVIII, pp. 365–366.
No. 7.—Gregory, W. K., and Conrad, G. M.: American Museum Novitates, 1937, No. 952.
No. 8.—LaMonte, F.: Bulletin N. Y. Zoological Society, 1937, XL, pp. 190–196.
No. 9.—LaMonte, F.: Natural History, December, 1937, pp. 762–766.
No. 10.—Conrad, G. M.: American Museum Novitates, 1937, No. 968.
No. 11.—Conrad, G. M., and LaMonte, F.: Bulletin American Museum, 1937, LXXIV, Art. 4.
No. 12.—Nichols, J. T.: Copeia, 1937, No. 4, pp. 236–237.

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growing at a greater rate than another part of the body— positive heterogony (positive allometry, Huxley and Tessier, 1936) or at a slower rate— negative heterogony (negative allometry). In the former case the constant differential growth ratio would be greater than unity, and the growth rate of the dependent variable (the organ or part of the organism) is maintaining a greater growth per unit increase than is the independent variable (the organism as a whole; in this paper it is designated by the body length). In the case of negative heterogony the growth ratio of the dependent variable to the independent variable is less than unity, with the reverse relationship. Isogony (isometry, Huxley and Tessier, 1936) is a specific condition of heterogony; the unit increases in growth of the two variables being equal and the proportions thus remaining undisturbed.

The formula, $y = bx^k$, has been applied in its logarithmic form, $\log y = k \log x + \log b$ (Huxley, 1932), to numerous data and shown to yield a straight line for a considerable range of differential growth between whole organs and the remainder of the body; i.e., large chela of the male fiddler crab, *Uca pugnax* (Huxley, 1927), and of the prawn, *Palaemon malcomsoni* (Huxley, 1932); the jaws of certain fishes, *Lepidosteus osseus*, *Belone*, *Hemirhamphus far*, and *Polyodon spathula* (Needham, 1935), relative to the length of the remainder of the body.

This formula implies that for the range over which it holds the relative growth rate of one variable to the relative growth rate of the other variable remains constant, the ratio itself being denoted by the value k. This exponent, k, denotes a coefficient of ontogenetic relative growth, as each increase in size is partitioned to the various parts of the organism in accordance with the relative growth function. Growth, therefore, is used in the sense of change in size during ontogeny.

For the data dealt with in this paper the growth coefficient, k, has been determined by computing the slope for the line representing the relative changes in size, during post-larval development, of two growing organs or parts of the body of the particular organism here studied.

In order to facilitate the treatment of material which has not been classified as to sex and has been subject to unknown environmental conditions, a standard, body length (x in the equation), has been arbitrarily chosen, and in this study of changing proportions the values for other organs and parts (y in the equation) are treated as relative to this standard. Statistical methods, because the amount of data available did not warrant them, have not been applied to determine the reliability of the growth constants. Therefore, in the interpretation of the data,

less significance has been placed upon the actual values of the constants than upon a comparison of the trends of growth exhibited by the various body measurements, all obtained in terms of increase in body length.

The coefficient b, which indicates what the value of y is when x is unity, can best be interpreted as providing the time element of any relationship. For example, at a b of zero the complex for the determination of both variables will begin to produce their characters, in conformity with the growth function, at the same moment. If the line of the curve crosses the abscissa or the ordinate it indicates that one of the characters has been produced in excess of the other for the time represented by the value of the intercept. In considering this statement it should be remembered that the percentage increase of the various organs may differ at various stages of development (Huxley, 1932; Needham, 1935), thereby resulting in altered intercept values. Therefore as no data on the larval growth of the material studied in this paper is available the significance of b cannot be interpreted in relation to the growth constant. The data available, however, show a considerable range in size, from 1950 mm. to 3040 mm. in length, and are sufficient for a study of proportional changes during the period of growth after all organs and parts of the body have fully differentiated.

The twenty-three specimens of the blue marlin can be considered as representing a post-larval ontogenetic series with a range in weight from 91 to 537 pounds. As growth progresses various readjustments and changes, dependent upon the respective growth rates, can be readily observed through the application of the logarithmic method. Genotypically the smaller marlin presumably does not differ from the giant sized specimen, but the size attained determines phenotypic differences which are self-evident only in the instances where body or organ changes are marked. At the same time a comparatively simple explanation—that growth is basically dependent upon the multiplication of living substance, each part of the organism having its own specific rate of development for a certain definite period of time determined by its genic complex—permits a ready explanation for changing proportions.

Body Weight

Keys (1928) finds that in the European herring (*Clupea harengus*, the California sardine, and the killifish (*Fundulus parvipinnis*) the body weight (W) increases more rapidly than the cube of the body length (L) multiplied by a constant (a) which is dependent upon the units in use and the general species form. When the logarithms of weight and length

are plotted (Fig. 1) a straight line is obtained which conforms to the equation $W = a(L)^n$. The exponent n is indicative of the rate of change of weight with length and can be determined mathematically by solving,

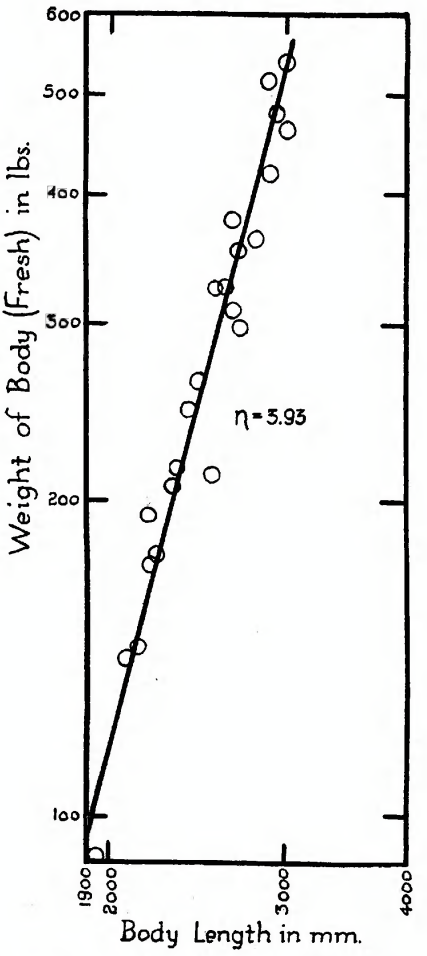

Fig. 1. Increase of body weight with increase of body length in the blue marlin, *Makaira nigricans ampla*. Logarithmic plotting both ways.

for any two points on the graph, the equation

$$n = \log W_2 - \log W_1 / \log L_2 - \log L_1$$

or can be calculated directly by reading the slope of the graph. Marshall, Nicholls, and Orr (1937) obtained for the herring from the Clyde

sea-area a similar result; the weight being proportional more nearly to the fourth power of the length than it is to the third. These results are in contradiction to the results obtained by earlier workers. Hecht (1916), on the basis of his study of eleven species of teleost fishes, concluded that weight is equal to a constant factor (dependent upon the "condition" of the fish at different seasons of the year) times the cube of the length. The rates of growth of various parts of the body (except depth) in terms of body length were identical, thus resulting in a body form that remains constant in each of the different species at various levels of post-embryonic development. The individual body form of a species Hecht attributed largely to variation in depth between species.

Because weight increases more rapidly than the cube of the length either the form of the fish or its specific gravity must change with adult growth. As specific gravity changes little in the balanced hydrostatic environment the conclusion is forced that the body form and therefore the proportions of the various dimensions are changing.

The present study of the blue marlin data confirms Keys' conclusion of the weight/length relation. The exponent n yields the value 3.93 (Fig. 1) and indicates that form change is occurring, even when the organs have been fully determined but are, as is characteristic of fishes, growing in the adult stages of their development. The blue marlin data adequately substantiates this hypothesis of form change by the fact that many of the organs and parts of the body are growing, during this period of indeterminate growth, that is being dealt with here, relatively faster or slower than the body length (Table 1).

Figures and Tables

The values of the growth constant, k, that have been determined for the part or organ relative to the body length are listed in Table 1. Graphic representations of differential growth ratios for various relationships are presented during the course of the text. Figure 2 has been drawn with the intention of illustrating the various proportional differences, which are to be described in detail, that are evident between a blue marlin which is 1950 mm. long and one that has attained a length of 3040 mm. These models have been reconstructed, not from the actual measurements of the parts and organs of specimens of these lengths, but from corrected readings taken from the logarithmic growth curves. Table 1. gives the actual measurements and the corrected readings for the organs and parts of the body that are listed.

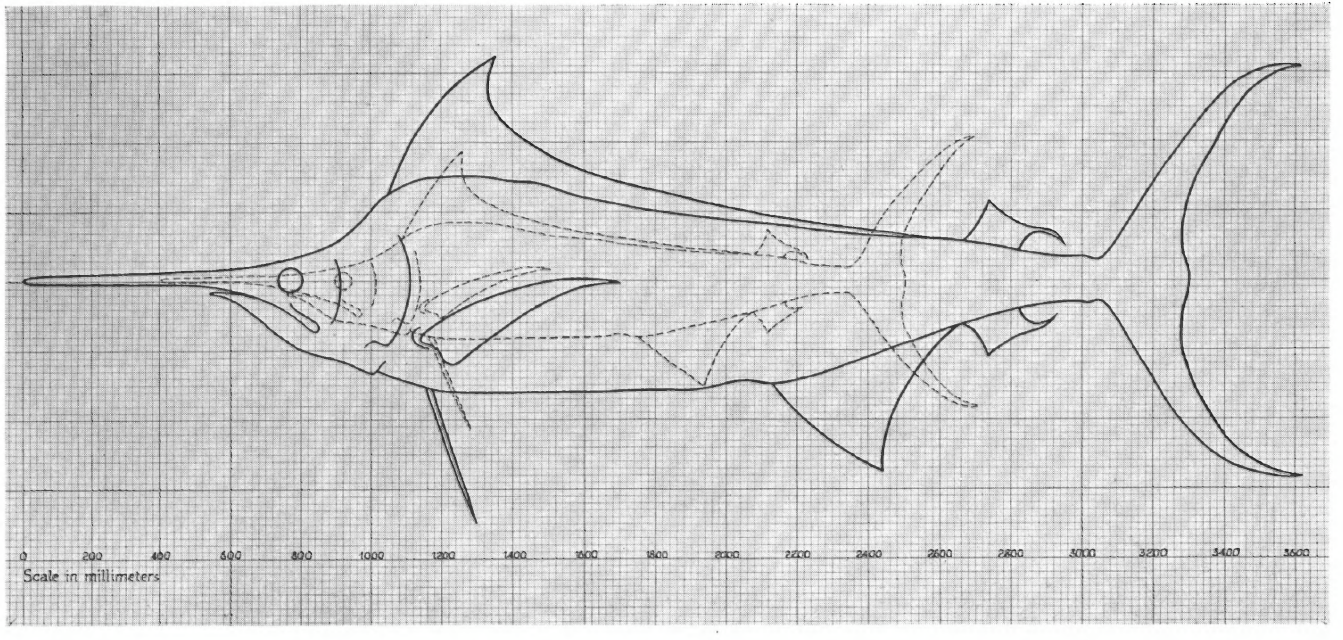

Fig. 2. Reconstructions of blue marlins at levels of development corresponding to body lengths of 1950 mm. (dash line) and 3040 mm. (solid line).

TABLE I—Equilibrium constants for various body measurements (ordinates) plotted against the standard, body length (abscissa) of *Makaira nigricans ampla*. The measurements for the body length range from 1950 mm. to 3040 mm.

ORGAN OR PART OF BODY	Equilibrium constant k	Range of absolute measurements in mm.	Range of corrected measurements (taken from the graphs)
Snout tip to ant. bord. eye	0.88	490– 730	495– 730
Body depth (max.)	1.45	330– 670	330– 625
Snout tip to transv. plane of max. body area	0.90	840–1315	840–1240
Transverse plane of max. body area to tail base	1.10	1110–1725	1115–1800
Tip of snout to summit of back	1.10	840–1338	810–1300
Maximum spread of tail	1.00	712–1095	770–1180
A. P. length of tail, middle line from min. width of pedicle	1.24	107– 260	150– 260
Oblique length caudal fin, dorsal moiety	1.00	550– 840	545– 840
Oblique length caudal fin, ventral moiety	1.04	525– 775	505– 810
Minimum depth of pedicle	1.34	67– 120	66– 118
First dorsal fin, length of base	1.14	920–1531	920–1520
Depth of first dorsal fin, longest ray	1.15	290– 465	290– 485
Second dorsal fin, A. P. length	1.54	65– 158	77– 152
Second dorsal fin, depth longest ray	1.24	72– 125	73– 125
Anal fin, length at base	1.16	435– 760	435– 720
Anal fin, depth longest ray	1.24	245– 415	240– 410
Pectoral fin, width of base	1.44	60– 117	62– 117
Pectoral fin, longest ray	0.98	396– 598	390– 605
Greatest width of body	1.43	165– 320	165– 315
Width across caudal pedicle	1.54	55– 115	58– 112
Tip snout to post. bord. operculum	0.92	735–1122	740–1100
Ant. bord. eye to post. bord. operc.	1.00	240– 397	245– 380
Head depth supraoccipital to isthmus	1.30	180– 340	195– 345

BODY DEPTH AND BODY WIDTH

The value for the depth constant, in terms of body length, is 1.45 (Fig. 3), which indicates that for each unit increment of body length, the body depth increases progressively at the same unit rate although the increase in depth is 0.45 of a unit more than one. It can be assumed that a growth rate in which increase in body depth with respect to body length follows a trend in which the former variable shows greater growth

per unit increase will necessarily provide for alterations in body form to occur concomitantly with increase in body weight. The added body weight is being distributed along the transverse diameter of the body to a more marked extent than it is being done lengthwise. Such changes are of importance to an organism that, in order to move about adequately in its liquid environment, must adhere to certain principles of streamlining.

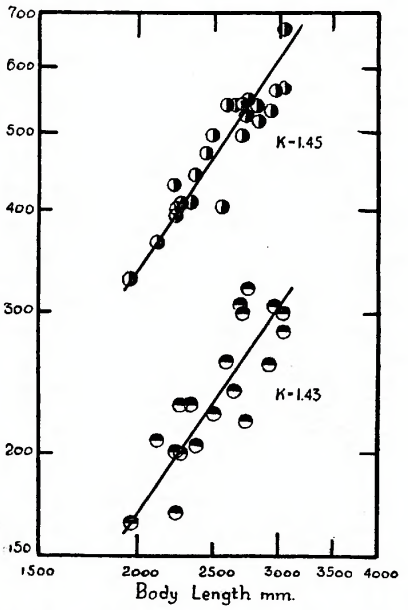

Fig. 3. Greatest width and greatest depth of body plotted against body length to show post-larval growth of these variables. Logarithmic spacing and measurements in millimeters both ways.

◑ greatest depth of body.
◓ greatest width of body.

Conrad and LaMonte (1937), using the terminology developed by Gregory (1928*b*) to distinguish the highly variable body form of fishes, designate the body form, including the sword, of the blue marlin mesosomatic (length five times the depth) and in a few cases dolichosomatic (length more than five and a half times the depth). The logarithmic curve for the body depth/body length relationship (Fig. 3) indicates that the smaller blue marlins are slender and therefore dolichosomatic but because of greater unit increases in body depth the body form, with increase in size, changes and becomes mesosomatic. This change in

proportion illustrates an interesting point in connection with streamlining; namely the change during post-larval development from a shallow entering angle to one that is relatively deeper.

Concurrent with the relatively greater increase in body depth there is a similar increase in the greatest width of the body, for which the rate of change in terms of body length yields a relative growth ratio of 1.43 (Fig. 3). Thus each unit increase in body length is accompanied by a greater and greater increase in body width, in conformity with the differential partition of growth in the two planes of length and maximum body width.

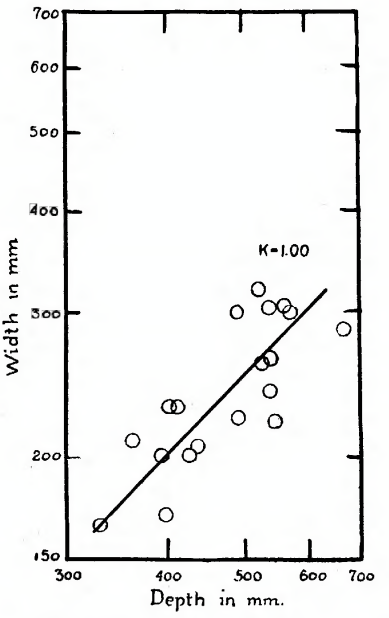

Fig. 4. Logarithmic graph showing increase of greatest width of body relative to increase of greatest depth of body.

It may be stated here that the two series of measurements of the depth and width of the pedicle taken at the minimum point of cross section also indicate that the transverse diameters of the body show a relatively greater partition of growth in this region; the constant differential partition of growth increments being 1.34 of a unit increase for the minimum depth of the pedicle as against each unit increase of body length and 1.54 for the increase of the width of the pedicle in terms of increase of the same standard. The probability is that if the added body weight is

distributed to the transverse diameters of the greatest cross section and of the pedicle in a greater proportion than it is to the body length, other cross sectional areas of the body (of which no measurements are available) will show a similar partition of growth.

The greatest width of the body/body depth relationship (Fig. 4) with a value of unity serves as a check upon the validity of the measurements considered above and indicates that the aforementioned relative increase in body weight is not only partitioned to a more marked extent to the transverse planes of the body as growth progresses but equally so to the various points of the maximum body girth. Thus an oval cross section is maintained, the area of which increases isogonically in the vertical and horizontal directions.

The plotting of the data for greatest width of the body results in an unusual degree of variability which probably can be attributed to sexual activity or to unknown environmental conditions such as the amount of food in the digestive system.

The modal types, that is the specimens falling upon the line of best fit for the body width/body depth relation (Fig. 4), all conform to a mesothoracic condition (body width 50/100 of body depth). The stenothoracic (body width less than 45/100 of body depth) stragglers that Conrad and LaMonte (1937) mention are those specimens that fall on the limits of variability below the curve. The upper limits of variability include those stragglers in which the body width is about 60/100 of the body depth and therefore are included in the mesothoracic category, as Gregory (1928*b*) states the index for mesothoracic fishes to be one in which body width is 45/100 to 1/1 of body depth. It is interesting to note that because the width/depth relationship maintains an isogonic increase of growth increments, at all levels of development the limits of variability range from about 40/100 to 60/100 with a mode in which the width is 50/100 of the depth.

Movement of Transverse Plane of Maximum Body Area

The partition of growth increments to the component parts of the total body length is of use in determining whether or not the transverse plane of maximum body area maintains a position which remains relatively constant between the snout tip and the tail base as the body weight and size increases and the depth and width are growing proportionately greater. Evidence for a forward movement of this maximum transverse body area is obtained from a consideration of the measurements of the "snout tip to the transverse plane of maximum body area" and the

"transverse plane of maximum body area to the tail base." Each, when plotted against the body length as the standard, exhibits a constant value for its relative growth rate, the former value being 0.90 and the latter 1.10 (Fig. 5). Thus in the course of post-larval development the streamline contours of the body are being altered in a manner to shorten the "entrance" of the fish through the water and increase the entering angle. The "run" is becoming relatively longer than the "entrance" and the angle formed by the postero-dorsal and the postero-ventral surfaces of the fish is smaller in specimens of greater size.

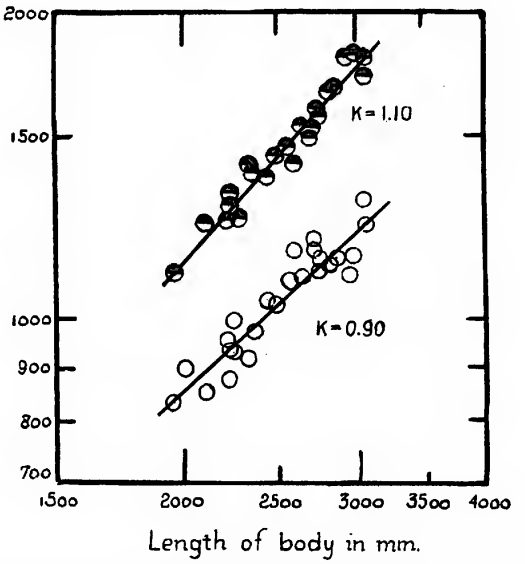

Fig. 5. Graph illustrating forward movement of greatest cross section of body. Abscissa represents length of body. Ordinates are: O–snout tip to transverse plane of maximum body area; ⊖–transverse plane of maximum body area to tail base. Logarithmic plotting.

Caudal Fin

Dimensional growth of the component parts of the caudal fin, the determinations of which are remarkably constant and accurate, indicating that variation affects this organ but little, yield results which are of further interest in connection with the relation that further proportional changes may have to streamlining. Several of the dimensions of the caudal fin—the dorsal moiety, the ventral moiety, and the spread of the tail—show little or no change in proportions but there is a marked increase in the anterior posterior length of the tail measured from the

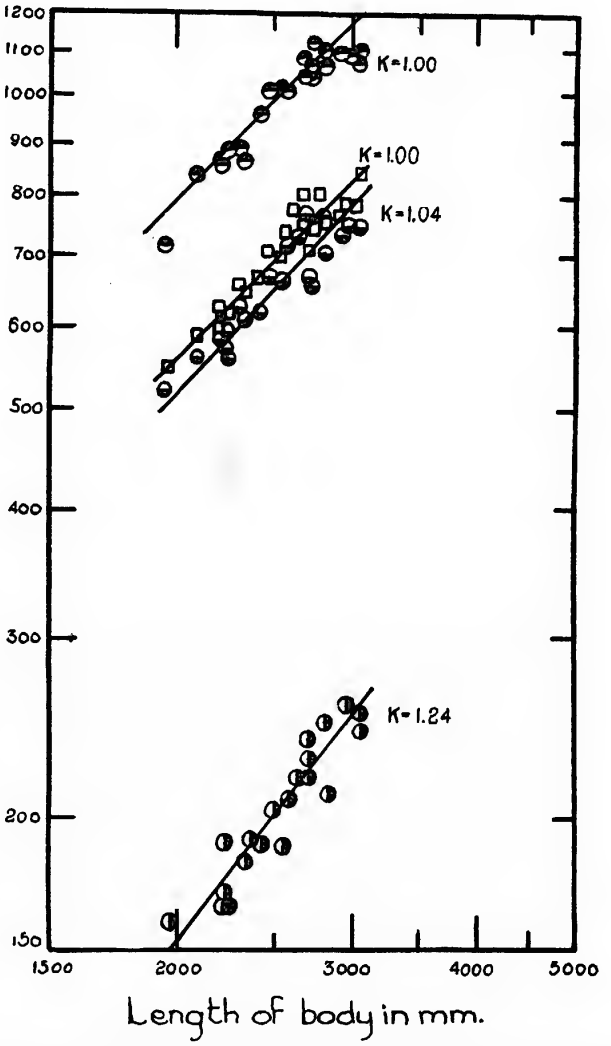

Fig. 6. Growth of dimensions of caudal fin (ordinates) relative to body length. Logarithmic plotting both ways.

◓ maximum spread of tail.
□ oblique length caudal fin, dorsal moiety.
◒ oblique length caudal fin, ventral moiety.
◑ A. P. length of tail, middle line from min. width of pedicle.

minimum width of the pedicle. As the growth of this part of the fin is relatively greater than that of the body length (k = 1.24, Fig. 6), and as the remaining parts of the caudal fin maintain the same proportions to each other and to the body length in specimens of all sizes, the result is a change in the concavity of the tail in such a manner as to provide the larger fishes with less of a concavity.

This change in the concavity of the caudal fin brings out an interesting problem suggested by Breder (1926). Just how is the fork of the tail connected with the speed that the fish may attain? The realization that a change in the proportion of the concavity of the tail results with increased size emphasizes the necessity for understanding the importance of the fork of the tail as an aid or possibly a detriment to streamlining.

The explanation given by Nichols (1915 and 1920) for the fork in the tail of fish; namely the water displaced by the cephalic portion of the fish should meet immediately upon leaving the converging curves of

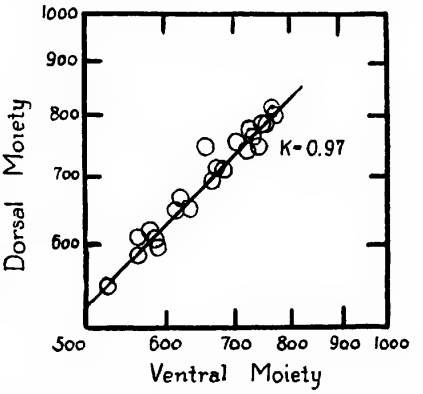

Fig. 7. Increase of dorsal moiety relative to increase of ventral moiety. Logarithmic plotting.

the body, would seem to contradict the relatively greater extension of the anterior posterior length of the tail. The marked increases of the transverse diameters of the body, however, would necessitate a greater anterior posterior length of the tail in order to provide for a less abrupt "run" and thus permit the displaced water to merge back of the fin at the optimum angle. Vacuums or eddies presumably will not be created nor will on the other hand, as is the case with fish that possess a square tail, any parallel runs of water be present to impede forward motion.

It is possible that the change in concavity may have less connection with streamlining than it does with the necessity for structural and mechanical modifications as the dorsal and the ventral moieties are becoming longer with increased size of the fish.

The tail, in the specimens of smaller size, is slightly although distinctly epibatic, but with greater size the tendency is for the attainment of a condition wherein the dorsal and ventral lobes will be symmetrical, although complete symmetry is not attained in any of the larger blue marlins. The growth gradient for the ventral moiety is slightly greater than that for the dorsal moiety (Fig. 6); the latter variable showing no proportional changes with body length ($k = 1.00$) whereas the ventral moiety shows a slight relative increase in terms of the standard ($k = 1.04$). This positive heterogony for the ventral moiety is extremely slight but is confirmed when its growth is plotted relative to the growth of the dorsal moiety, with a resultant greater partition of growth to the ventral lobe of the fin. The value of the constant is 0.97 (Fig. 7) and because of the almost perfect fit of the values on the growth curve it can be conceived as possessing some measure of reliability.

Longitudinal Appendages

The function of the longitudinal appendages—the first and second dorsals and the first and second anals—are primarily of advantage in steering the fish and acting as a brake in stopping side way thrusts of the sword (Gregory and Conrad, 1937). The rate of change of the length of the first dorsal fin with body length yields a proportional rate of increase of 1.14, indicating that as body length is increasing the relative increase of the length of the first dorsal is markedly greater by fourteen hundredths of one unit. The depth of the fin as measured by the length of the longest ray shows approximately the same relative increase with greater body size. Table 1 lists the growth constant values for the second dorsal and the anal (measurements of the anal are of the first and second anals combined) which are indicative of similar modifications; all showing positive heterogonic growth as compared with body length. Such results may be taken as an indication that with increased body size and the handicap of increased body weight the necessity is placed upon the fish of maintaining a greater efficiency in balancing and steering. Presumably this may account for the growth of fins conforming to a growth partition in which their area is increasing relatively greater than is the body length.

Pectoral Fins

Breder (1926) in his discussion of the scombriform fishes states that "the pectorals are typically stiff and without much mobility and are used almost entirely for wheeling and turning." The results obtained for the proportional growth of the pectoral fins of the blue marlin indicate that with unit increase in body length the width of the base of the pectorals is increasing at a rate of nearly one and one half times greater ($k = 1.44$), whereas the length of the fin, taken by measuring the longest ray, is maintaining an isogonic increase in terms of body length. It would seem that there is a necessity for a more efficient means of turning the fish which could not be maintained with increased body size and weight unless the pectoral fin became proportionately larger. A stouter but not a longer one is the manifestation of such a mechanical requirement.

Head Measurements

A detailed study of the head measurements, expressed as the rate of change of its component parts with body length, illustrates a number of details which are of importance in forward movement, as the head and the portion of the body anterior to the greatest cross section provides an entering wedge for forward motion of the fish. As stated previously the portion of the fish anterior to the greatest cross section is growing at a relatively slower rate than is the entire body length. When this anterior part of the fish is broken up into a number of its dimensions—the tip of the snout to the posterior border of the operculum, the tip of the snout to the anterior border of the eye, and the anterior border of the eye to the posterior border of the operculum—it becomes evident that each smaller part has its specific growth coefficient (Fig. 8). These coefficients are presumably in turn the sum of growth rates existing for still smaller component parts, just as the constant for the tip of the snout to the posterior border of the operculum yields a value which can be considered a component of the growth values for two of the dimensions composing this larger part. For example the length of the head as measured from the tip of the snout to the posterior border of the operculum is increasing at a smaller unit rate than the body length ($k = 0.92$). One of the components of this dimension, the snout, as measured from the tip of the snout to the anterior border of the eye, shows a somewhat smaller unit increase ($k = 0.88$). The relatively greater increase of the part extending from the anterior border of the eye to the posterior border of the operculum accounts for the difference in growth rates be-

tween the snout and the head including the snout. This variable, which is indicative of head length minus the snout, is having growth partitioned to it at the same rate as is the body length as a whole ($k = 1.00$).

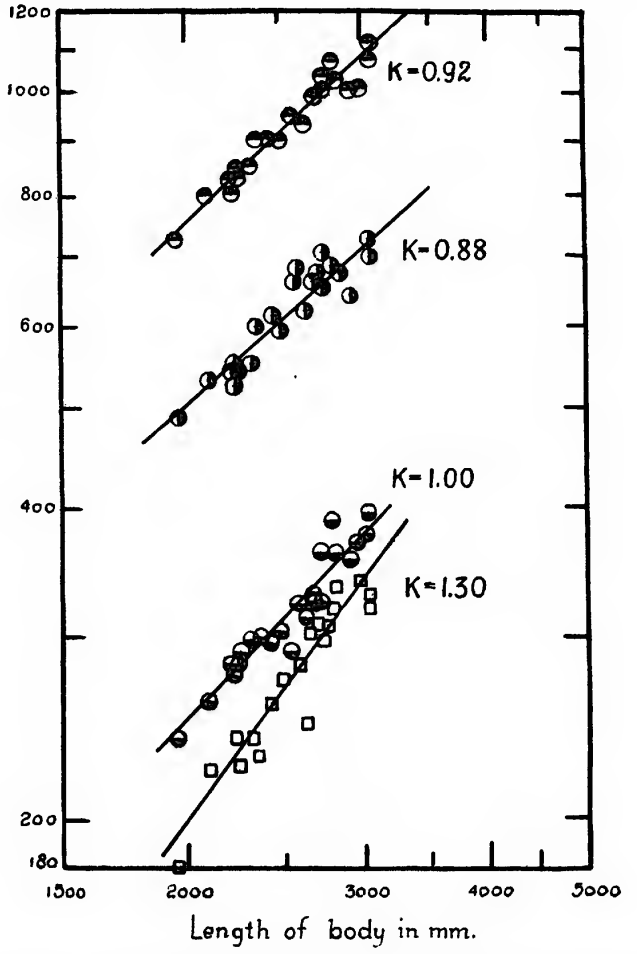

Fig. 8. Component parts of head (vertical values) plotted against length of body. Logarithmic plotting.

◓ tip of snout to post. bord. operculum.
◑ snout tip to ant. bord. eye.
◒ ant. bord. eye to post. bord. operculum.
□ head depth supraoccipital to isthmus.

It has been stated that the entering wedge of the blue marlin is becoming increasingly larger as the fish itself increases in size. Therefore it is to be expected that the head depth would show a corresponding rela-

tive increase. The value of the constant for change of head depth with body length is 1.30, but this falls short of the 1.45 value obtained for body depth, indicating that in the larger fishes the dorsal surface of the body from the snout to the summit of the back is becoming deeper and the concavity on the dorsal surface of the head is assuming a condition which indicates inferior streamlining of the body form in the larger specimens. Presumably a greater concavity would cause greater resistance to forward motion through the water as retarding eddies would be introduced. This is incompatible with Gregory's (1928*a*, p. 410) assumption that the size and proportions of the head to those of the body as a whole are regulated so that a streamlining which is presumably efficient results normally.

The prominence of the snout obscures the fact that relative to body length it is showing a decreasing amount of growth, the growth coefficient being 0.88. This negative heterogony is analagous to the result that Needham (1935) obtained for *Lepidosteus osseus*, where an early period of rapid growth is obtained in order to provide the young predacious fish with a jaw of adequate length for feeding purposes. As soon as the snout attains a required length, however, the growth rate becomes negative as it does in the blue marlin where lack of larval measurements make it only possible to suppose that the early growth of the snout was markedly heterogonic in a positive direction. Otherwise the snout could not have attained the prominence that it has.

DISCUSSION

The value of this study of growth is first that it tends to confirm the presence of a mechanism regulating the relative growth of the component parts of an organism as a simple function of the growth of the entire organism. Secondly it suggests that there is possibly a correlation between these seemingly precise growth rates and the necessity for such controlled changes. In the case of the blue marlin, increased size and weight places upon the organism the necessity of coping with the environment in a constantly differing way. The proportions of the various components are shown to change, but are these changes of mechanical and functional advantage in complying with streamline requirements? With the higher vertebrates growth proceeds to a definite stage of development and then ceases, except in a few isolated cases, i.e., in the voles (Hinton, 1926), in man (Hrdlicka, 1936). Fish go through a period of marked changes during the larval stage and then continue to grow and change less rapidly. This slow post-larval growth, with its

relatively greater increase in body weight, is perhaps the main cause for various dimensions of the body growing disproportionately. Even if the medium does not affect the direction of growth of these dimensions by selection there may be a need for adjusting certain factors (size of the organs and parts) to maintain an efficient mechanism for the locomotion of the organsim as the body weight increases.

The positive or negative heterogony shown by the different parts of the blue marlin produce at each level of growth a body form proportionately different from an earlier stage. With the aid of such measurements and the means for reconstructing and testing representative models embodying such changes in proportions it should be possible to determine their value in relation to streamlining.

There are two alternatives possible in considering the time of development at which the factors for the production of the growth rates indicative of the post-larval stages have their initial effect. First, the heterogony exhibited by the various organs may have been determined during the early larval period of growth and the proportional changes in the adult phase of growth are not as marked as they are in the larval period where the actual rates of growth (the multiplication of living substance) are far more rapid than they are in the indeterminate period of growth studied. In such a case the relative rates of growth would remain the same or nearly the same for the entire life of the organism, the actual increments of organ increase per unit time being larger in the larval stage. This supposition would mean that determination of adult body form in the larval stage would reduce the emphasis that has been placed upon added body weight as being the contributing factor for proportional alterations in the relative sizes and shapes of the organs and parts of the body during post-larval development.

The alternative to relative growth rates being determined early in ontogeny is obviously a change at some period of development, probably at the time when differentiation of the organs have been fully completed, yet added growth and therefore added weight requires that there be some adjustment of proportions. Evidence for the latter belief is indicated by the results which Needham (1935) obtained. Growth of the jaws of *Lepidosteus osseus*, *Belone*, and *Hemirhamphus* relative to the rest of the body show two distinct periods of growth, the growth coefficient being much greater in the first than in the second period. This difference in growth rates is correlated with differences in the histology of the growing jaws and with larval adaptation by the young fish of the predacious elongated jaws of the adult.

SUMMARY

Huxley's relative growth method is used to measure the relative amounts of growth exhibited by various organs and parts of the blue marlin (*Makaira nigricans ampla*). The exponent k in the equation $y = bx^k$ denotes a coefficient of partition of growth increments and is thus an indication of the proportional changes occurring during the post-larval development of the fish.

Body weight increases more rapidly than the cube of the body length. This indicates that form change is occurring during the indeterminate period of growth of the blue marlin.

The added body weight is being distributed along the transverse diamaters of the body to a more marked extent than it is being done lengthwise. Because of these proportional changes the dolichosomatic body form of the early post-larval fish assumes a mesosomatic condition.

The transverse plane of the maximum body area shows a constant relative forward movement as the fish attains greater size. This alters the streamline contours of the body so as to shorten the "entrance" of the fish through the water and lengthen the "run."

The concavity of the caudal fin becomes increasingly shallower as the fish becomes larger. This is brought about by a relatively greater extension of the anterior posterior length of the fin while the other components show almost no proportional changes.

The longitudinal appendages all show positive heterogonic growth in terms of increase in body length.

Proportional changes of the pectoral fin are evidenced by a relative increase in the stoutness of the fin. The length increases isogonically in terms of increase in body length.

The component parts of the head all show different rates of growth. Relative to the body length the snout shows a decreasing amount of growth.

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